Introduction to Global Positioning Systems (GPS)

U.S. Army Corps of Engineers / NOAA Coastal Services Center Training Partnership

Outline

Introduction to GPS

- Overview of Global Positioning Systems
  - Theory and how the system works
  - Sources of error and differential correction
- Working with GPS
  - Applied Uses
  - Receivers
  - Plan for Data Collection
- Field Data Collection Activity
- GPS/GIS Data Integration
  - Differential Correction Process
  - ArcPad

Overview of Global Positioning Systems (GPS)

What Is GPS?

Overview of GPS

Technology to measure/estimate a location on the surface of the Earth

Why should I use GPS?
What are its uses?

– GPS allows you to determine where you are on the surface of the Earth at all times

– With GPS, you can plot a certain location and return to that spot at a later time

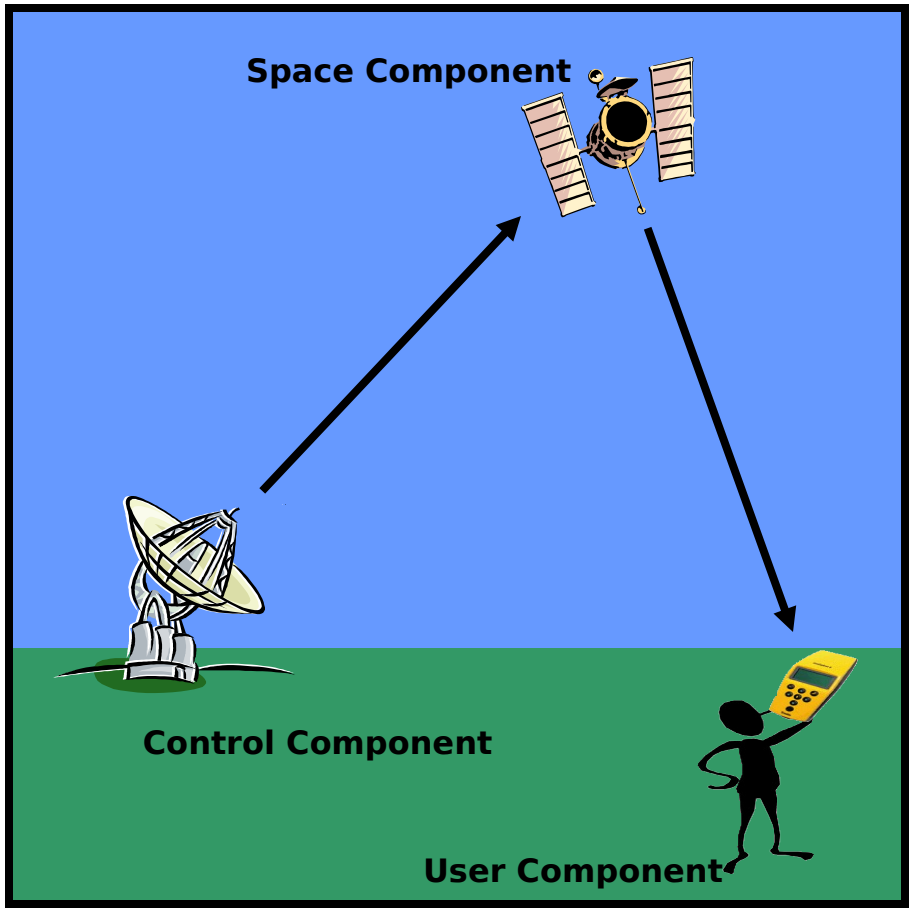
– GPS can help locate critical habitats, marine boundaries, species observation points

– GPS provides a fast and accurate way to collect spatial data

How Does GPS Work?

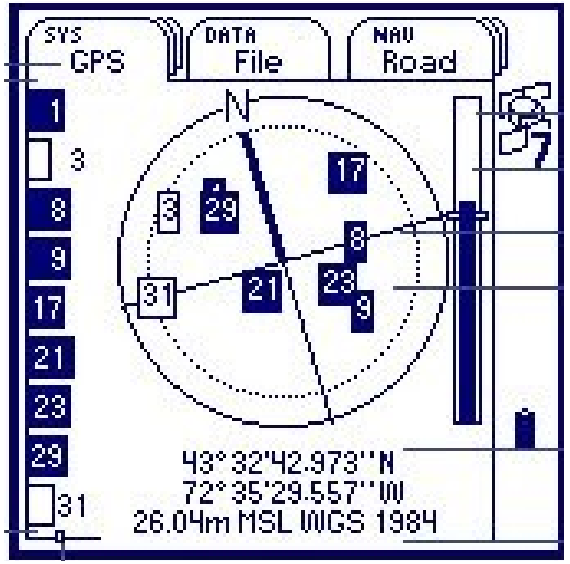
Overview of GPS

- **3 main components:**
  - Space component (Satellites)
  - Control component (Monitoring Stations)
  - User component (Receivers)
- **Receivers determine position by calculating distance to four or more satellites**
- **U.S. GPS (NAVSTAR) developed by the Department of Defense in 1978**
  - Soviet Union - GLONASS
  - European Union - Galileo



Determining Satellite Position

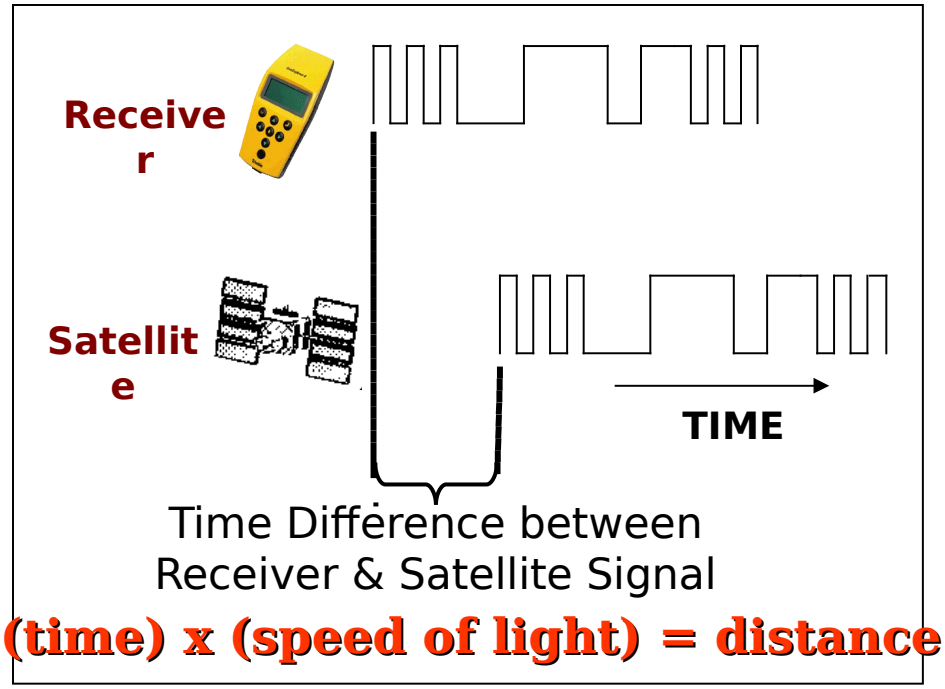
- **Receiver must know where satellites are located to calculate own position**
- **GPS receivers have an almanac programmed into their computers**
  - Tells receiver approximate position of satellites at any given time
- **Ground control stations constantly monitor and correct orbits**
  - Correction information is sent to satellites to be broadcast to receivers



Almanac-based sky plot of satellite positions relative to GPS unit

Determining Distance to Satellite

- **Satellite sends digital code to earth**
  - Constantly repeating pseudo-random timing code (C/A)
  - Also contains orbital and time corrections
- **Receiver measures time for code to reach it**
  - Receiver generates replica of code
  - Receiver compares the code to get time offset
- **Time x Speed of Light = Distance**



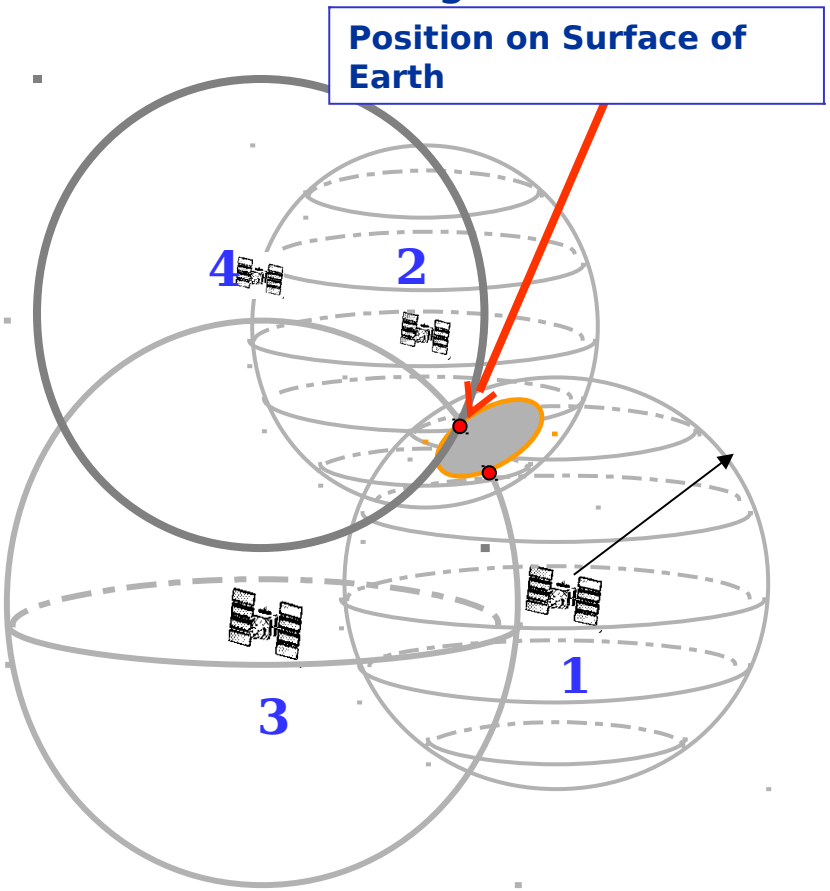
Determining Position on Earth

Overview of GPS

- **3 satellites are needed with perfect measurements**
  - 1 distance value = a sphere
  - 2 distance values = a circle
  - 3 distance values = 2 points on a circle
    - **Compute the horizontal position (can throw one out)**

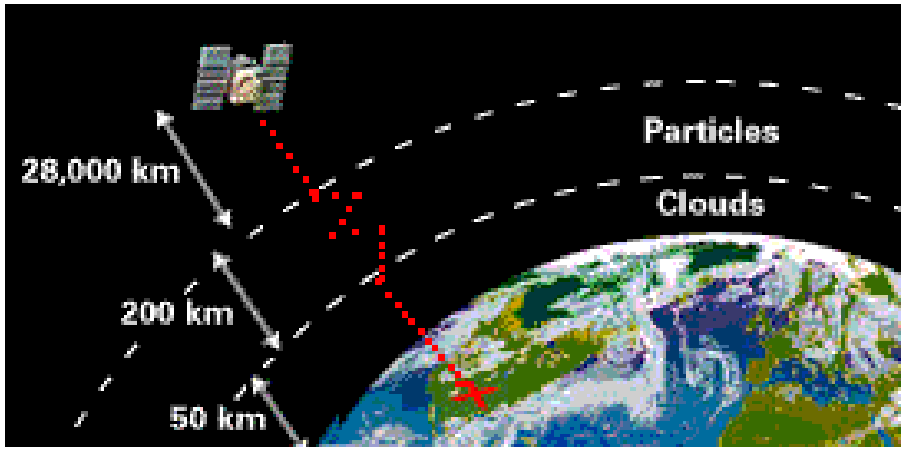
- **4 satellites are needed in reality**
  - Corrects errors in receiver clocks
  - Corrects errors in distance measurements

- **Poor vertical calculations**
  - 1.5 to 3 times greater error



Problem: Internal Sources of Error

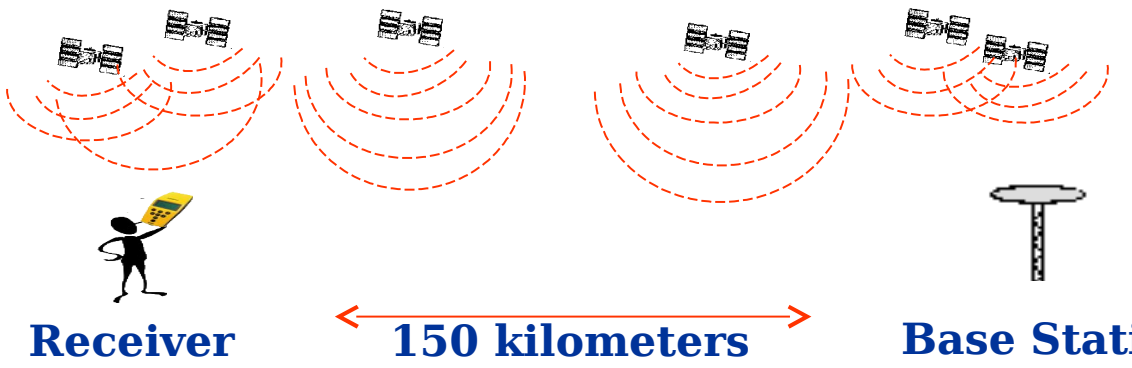
- **Selective Availability (S/A)**
  - Deliberate degradation of signal by Dept. of Defense
  - Error up to 100 meters
  - May 1, 2000, S/A turned off
  - Could be turned back on at any time
- **Ephemeris**
  - Minor disturbances of satellite orbit
  - Caused by gravitational pull of sun and moon
  - Corrected by monitoring stations
- **Atmospheric delays**
  - Currently, largest source of error
  - Error up to 10 meters
  - Can be corrected



Solution: Differential Correction

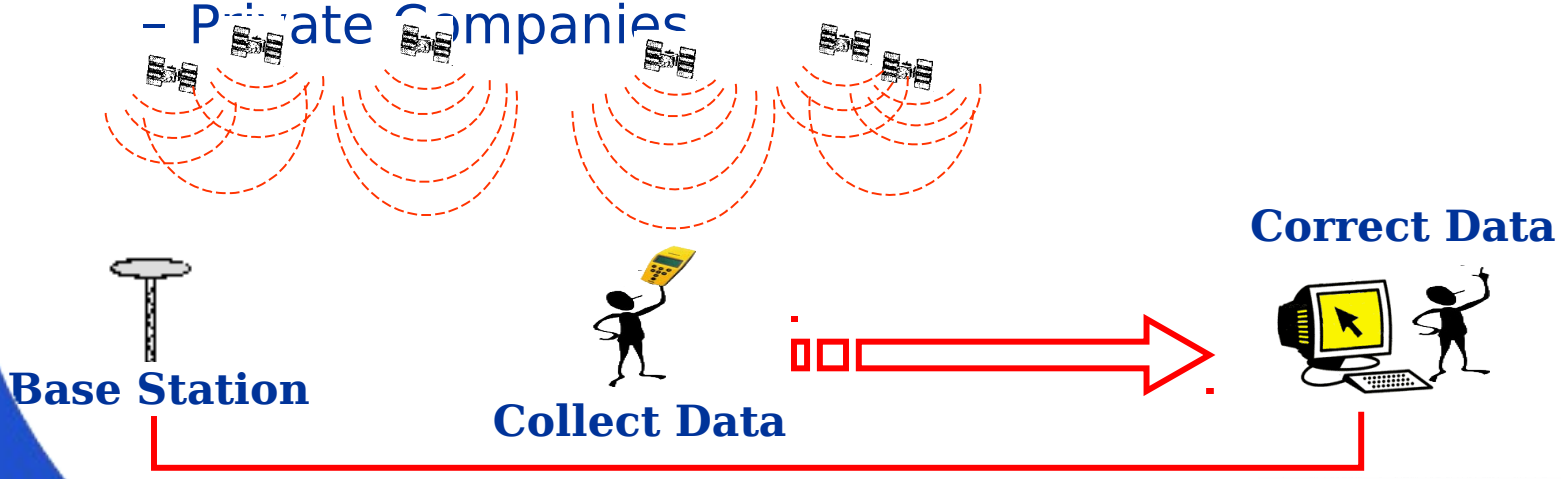
- **Process by which GPS positions are corrected for errors**
- **Two different types:**
  - Post-Processed
  - Real-Time
- **Which type do you need?**
  - Depends on application

- **Base station**
  - Position known to a high degree of accuracy
  - Calculates estimated location
  - Compares with known location
  - Receiver and base station use same satellites – same errors
  - Recommend receiver be within 150 to 200 kilometers of a station



Postprocessed Differential Correction

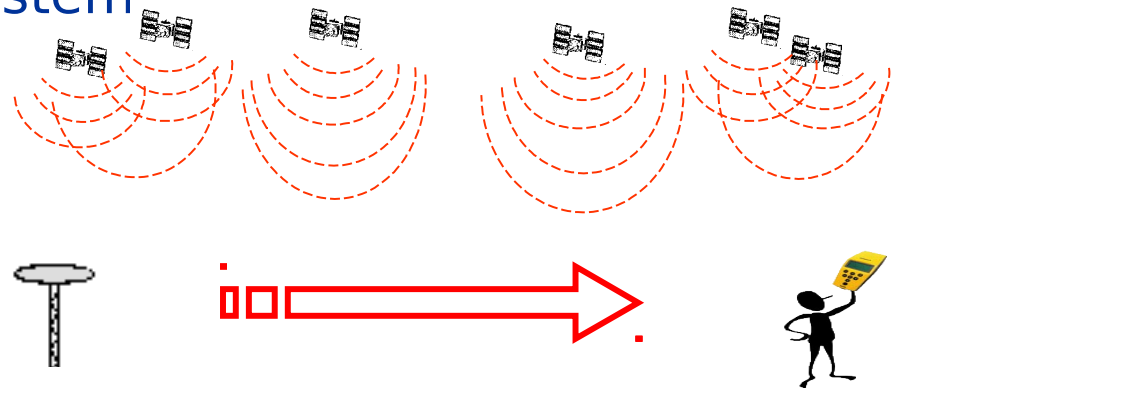
- **Base station receives signal and computes error file**
- **Software needed to apply corrections to rover file**
- **Accuracy: 1 to 3 meters after processing (10 meters in the field)**
- **Base station providers**
  - National Geodetic Survey
  - State Offices of Geodetic Survey
  - Colleges and Universities
  - Private Companies



Real-Time Differential Correction

Overview of GPS

- **Base station transmits position correction to roving receiver**
- **Computes error difference in receiver – real-time (“on-the-fly”)**
- **Accuracy: 1 to 3 meters in the field**
- **Real Time Correction Providers:**
  - U.S. Coast Guard
  - WAAS System



Differential Correction Example

Corrected A & B

Working with GPS

Common Applications

Working with GPS

- **Recreation**
- **Navigation**
- **Spatial data collection/mapping**
  - Locate sea turtle nests
  - Map research plots
  - Control points or ground truth for aerial photos or satellite imagery
- **Application Needs**
  - Real-time or post-processing?
  - Accuracy requirements - 1 meter or 20 meters?

GPS Receivers

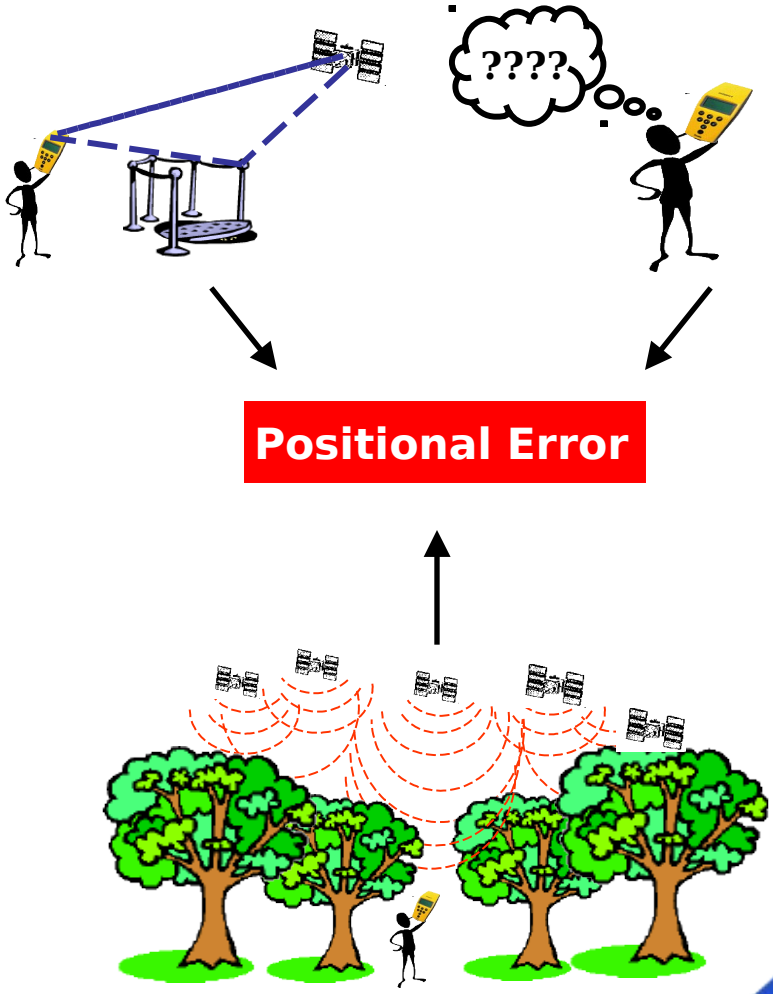
Working with GPS

Receiver	Features									
	Accuracy	#of Channels	Real-time	Post-processing	Data Logging	Complex Data Logging	Cost	Display	Data Streaming	External Processing Software
Recreational	3 - 10 m	6-12	Yes	No	Simple	No	$	Maps, but limited selection	Yes	No (limited, if do)
Navigational	1 - 3 m	9-12	Yes	No	No	No	$$	Navigational charts	No (usually)	No
Mapping	1 - 10 m	6-12	Yes	Yes	Yes	Yes	$$$	Maps, can import own data sets	Yes	Yes
Surveying	~cm	9-12	Yes	Yes	Yes	Yes	$$$$	-	Yes	Yes

Problem: External Sources of Error

Working with GPS

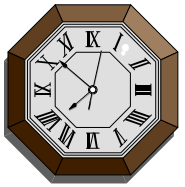
- **Multipath**
  - Signal bounces off an object
  - Receiver picks up delayed or two signals
  - Glassy or metal objects
- **Obstructions**
  - Signal can not penetrate matter
  - Tree canopies and buildings
  - Maximize number of satellites
- **Human Error**
  - Unpredictable
  - Collection/field techniques



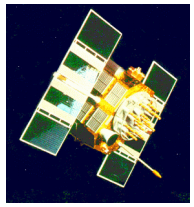
Solution: Plan for Data Collection

Working with GPS

- What data are we going to be collecting?
- What features will be used to represent this data?
- How should I collect these features?
- How are these data going to be attributed?
- Where are these data going to be mapped?
- How are these data going to be used?
- What are the ideal collection times?
- What are the optimal settings for the rec



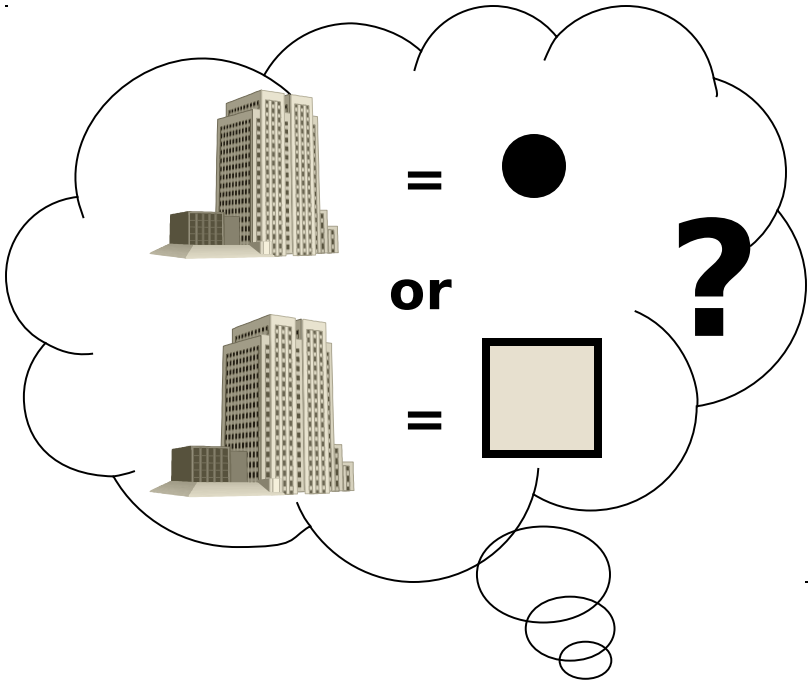
Shape	Descriptio	Std_dev	Gps_height
Point	BOAT.LAUNCH	1.878298	-26.616
Point	HOLIDAY.LOT.1	9.089902	-24.243
Point	HOLIDAY.LOT.2	5.673835	-25.928
Point	FOLLY.MARINA	4.959926	-27.549
Point	10.&.ERIE	4.891767	-26.072
Point	4.&.INDIAN	8.320358	-27.663
Point	FOLLY.BEACH.PARK	1.225874	-29.583
Point	SPEARFISH.&.OAK.ISL	2.133012	-32.992
Point	BOANS.ISLAND	7.285117	-19.649
Point	SOL.LEGEARE.PIER	2.173421	-29.710



What Features Will Be Used to Represent This Data?

Working with GPS

- **Similar to GIS, a GPS represents geographic phenomena as points, lines, or areas**
- **Scale plays a large part in how you decide to represent your data**



How Should I Collect These Features? Points

Working with GPS

- **Receiver is stationary**
- **Many positions per point**
  - Averaged together
  - Increases accuracy to 1-5 meters
  - 50-100 positions for post-processing units
  - 1-5 positions for real-time units

How Should I Collect These Features? Lines

Working with GPS

- Receiver is roving/moving
- Each position is a vertex in the line
- Joined by time
- Continuous motion
- Logging interval dependent on complexity of feature (1 to 5 seconds)
- Techniques differ depending on feature

How Should I Collect These Features? Areas

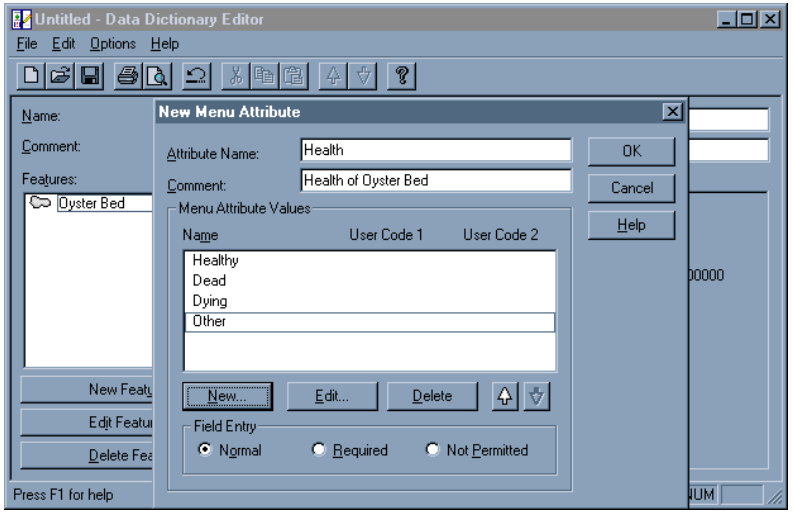
Working with GPS

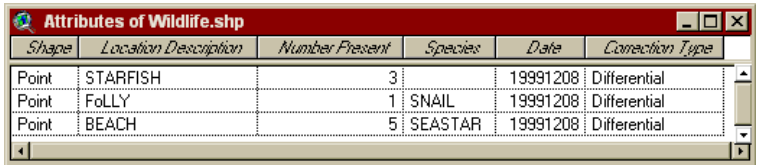
- **Similar to line feature**
- **First and last point the same**
- **Continuous motion**
- **Logging interval dependent on complexity of feature (1 to 5 seconds)**
- **Techniques differ depending on feature**

How Are These Data Going to be Attributed?

Working with GPS

- **Attributes are information associated with spatial locations**
- **Important element to mapping receivers**
  - Saves effort in field; attributes included with spatial features
  - Information structured using Data Dictionary file




Attributes of Wildlife.shp
Shape | Location Description | Number Present | Species | Date | Correction Type
Point | STARFISH | 3 | | 19991208 | Differential
Point | FoLLY | 1 | SNAIL | 19991208 | Differential
Point | BEACH | 5 | SEASTAR | 19991208 | Differential

Where is the Data Going to be Collected?

Working with GPS

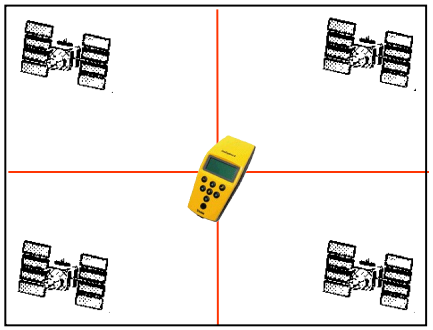
- **What are the site conditions?**
- **Obstructions**
  - Roofs, tall buildings, ships?
- **Multipath**
  - Fences, metal buildings?
- **Is the data you want to collect accessible?**
  - Techniques exist that allow you to collect data at an offset or spatial average

What Are the Ideal Collection Times?

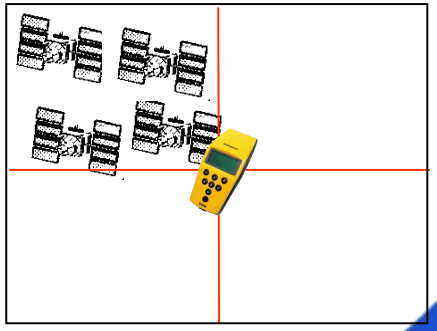
Working with GPS

- **Need to know where satellites are and their arrangement**
- **Two concerns**
  - Number of satellites
  - PDOP (position dilution of precision)
- **Almanac Information**
  - Downloaded by receiver with satellite signal
  - Internet sources
- **Source for prediction software/information**
  - Internet Web sites
  - Downloadable software on Internet
  - Available with most mapping-grade receiver software

Good configuration
Low PDOP Value (<6)



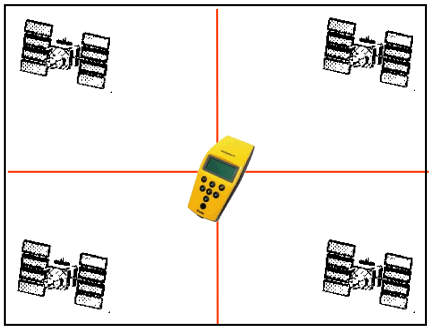
Bad configuration
High PDOP Value (>9)



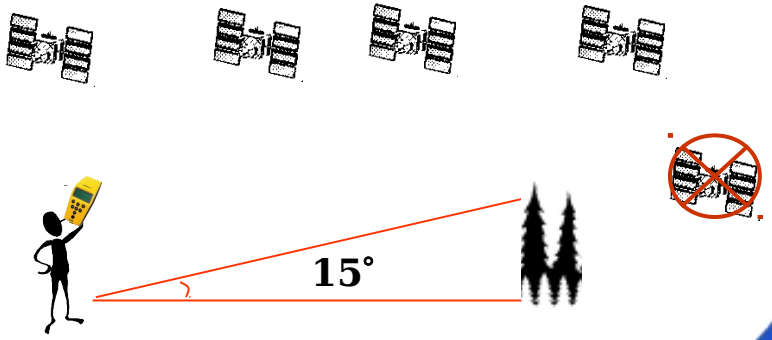
What Are the Optimal Receiver Settings?

Working with GPS

- **PDOP**
  - < 6 is good
  - > 9 should not be used



- **Elevation Mask**
  - Mask out satellites low to the horizon
  - Lower satellites introduce greater multipath and atmospheric errors
  - 15 degrees is common
  - Higher is better



What Are the Optimal Receiver Settings?

Working with GPS

- **SNR (Signal to Noise Ratio)**
  - Types of Noise
    - **Natural**
    - **GPS unit or antenna**
    - **Satellite**
  - Basically Static
  - Want high signal to low noise ratio
  - Higher values are better
  - > 6 is good

- **Position Mode**
  - Minimum number of satellites required
  - 2-dimensional
    - **Requires only 3 satellites**
    - **Altitude required; known and constant**
    - **Not recommended**
  - 3-dimensional
    - **Requires 4 satellites**
    - **Best option; used for mapping**
  - Over-determined 3-dimensional
    - **Requires 5 satellites**
    - **Maximize accuracy**
    - **Longer time to record data**

Field Data Collection Activity

1. Demonstrations:

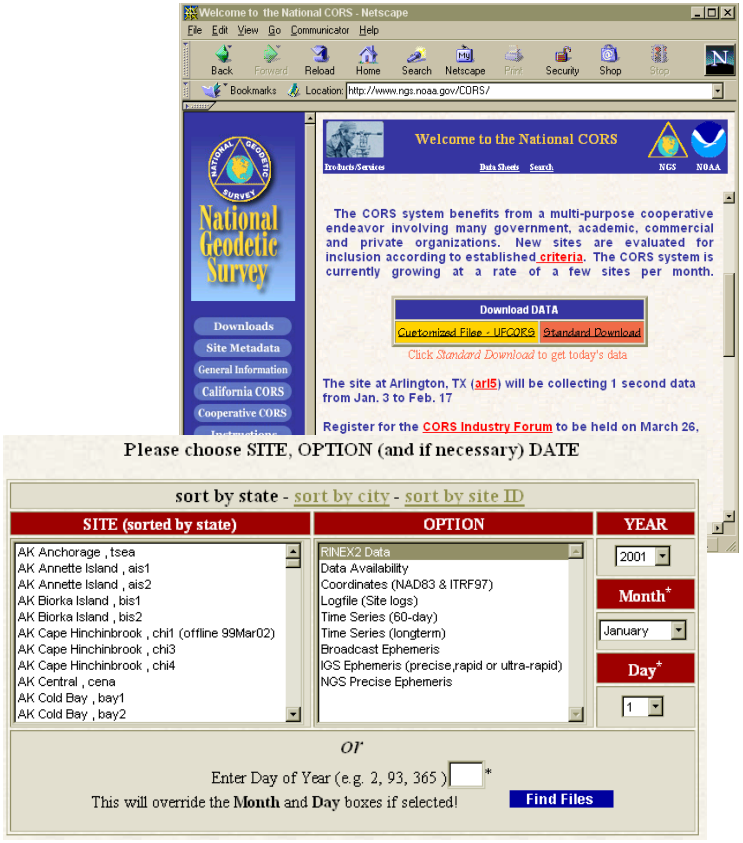
Data Dictionary Creation
Unit Setup and Operation

GPS/GIS Data Integration

Differential Correction Process

GPS/GIS Data Integration

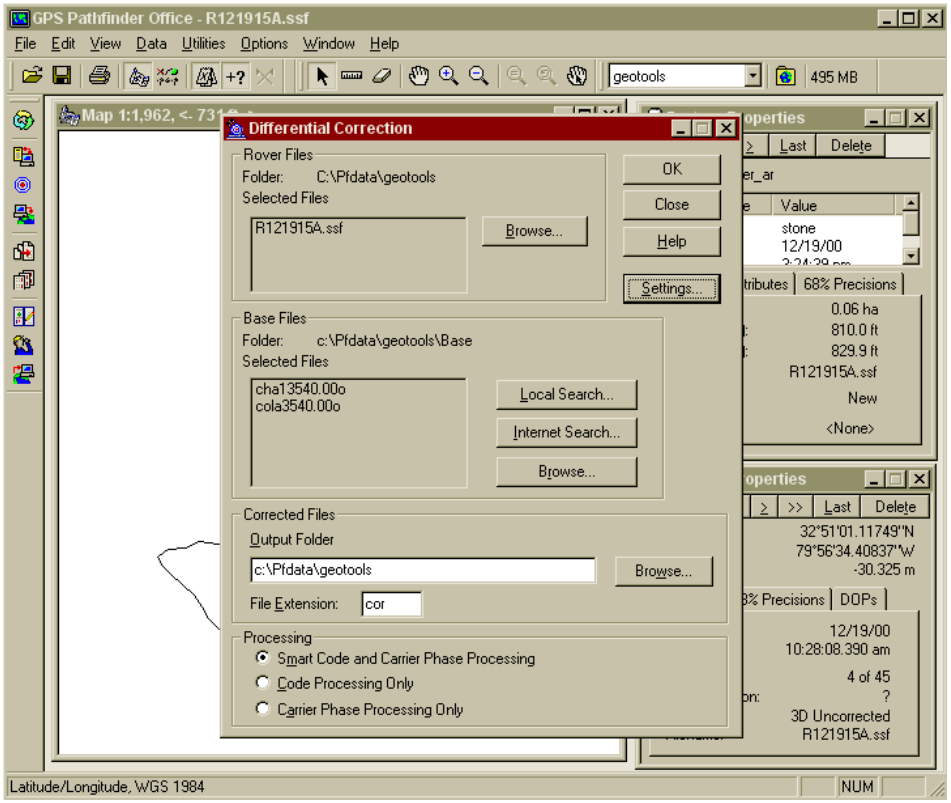
- **Manual Corrections Acquisition:**
  - Go to NGS (or other) home page
    - *www.ngs.noaa.gov*
  - Find the CORS (continuously operating reference stations) home page
  - Search for base station and date(s) in field
  - Download data to computer
  - Apply to rover file using Pathfinder Office software


Welcome to the National CORS - Netscape
Welcome to the National CORS
National Geodetic Survey
Downloads
Site Metadata
General Information
California CORS
Cooperative CORS
The CORS system benefits from a multi-purpose cooperative endeavor involving many government, academic, commercial and private organizations. New sites are evaluated for inclusion according to established criteria. The CORS system is currently growing at a rate of a few sites per month.
Download DATA
Customized Files - UFCORS
Standard Download
Click Standard Download to get today's data
The site at Arlington, TX (arl5) will be collecting 1 second data from Jan. 3 to Feb. 17
Register for the CORS Industry Forum to be held on March 26,
Please choose SITE, OPTION (and if necessary) DATE
sort by state - sort by city - sort by site ID
SITE (sorted by state)
OPTION
YEAR
AK Anchorage , tsea
AK Annette Island , ais1
AK Annette Island , ais2
AK Biorka Island , bis1
AK Biorka Island , bis2
AK Cape Hinchinbrook , chi1 (offline 99Mar02)
AK Cape Hinchinbrook , chi3
AK Cape Hinchinbrook , chi4
AK Central , cena
AK Cold Bay , bay1
AK Cold Bay , bay2
RINEX2 Data
Data Availability
Coordinates (NAD83 & ITRF97)
Logfile (Site logs)
Time Series (60-day)
Time Series (longterm)
Broadcast Ephemeris
IGS Ephemeris (precise,rapid or ultra-rapid)
NGS Precise Ephemeris
2001
Month*
January
Day*
1
or
Enter Day of Year (e.g. 2, 93, 365)
This will override the Month and Day boxes if selected!
Find Files

Differential Correction Process

GPS/GIS Data Integration

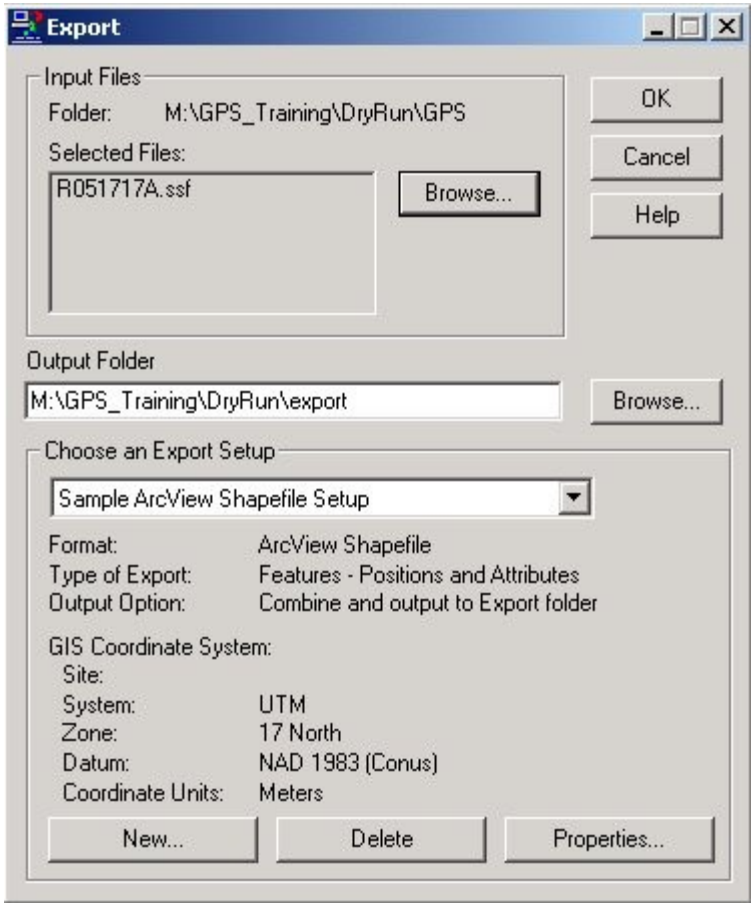
- **Methodology:**
  - Look at data set/map, correct if necessary
  - Look at attributes, correct if necessary
  - Use utility to differentially correct data
  - Set correction options
  - Make sure you have full coverage (time)
  - Process information
  - Look at final map of corrected data



Bringing Data into the ArcGIS World

GPS/GIS Data Integration

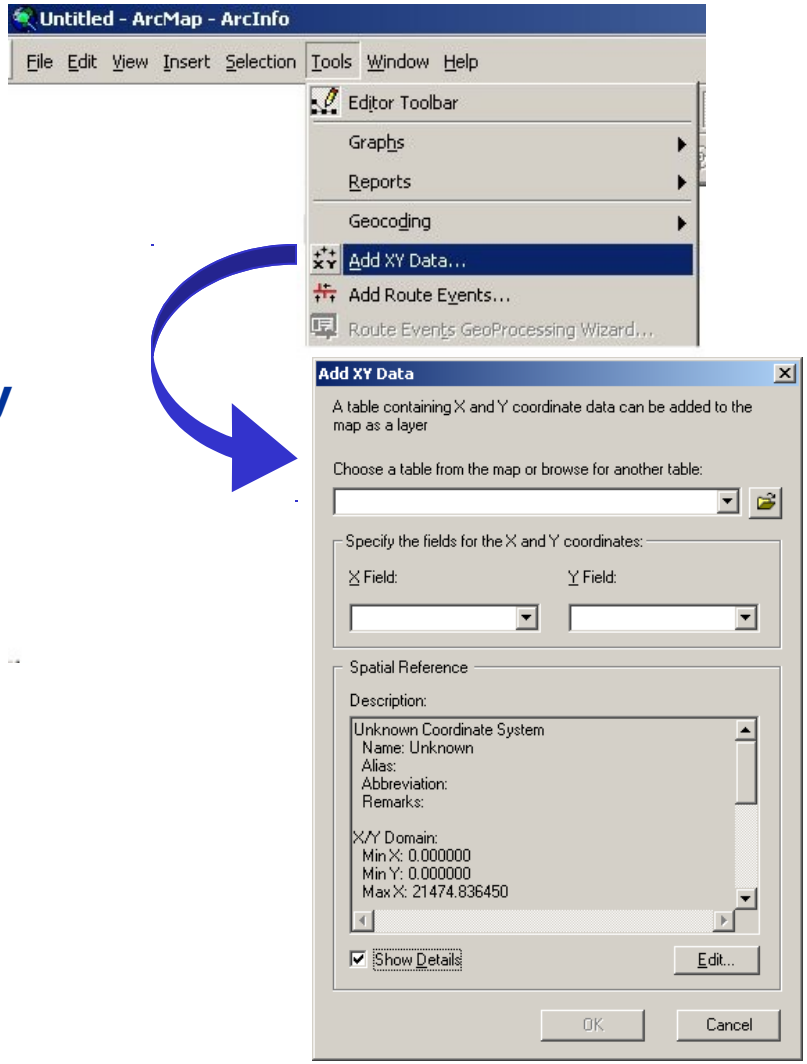
- **Methodology:**
  - Export data using Pathfinder Office Utility
    - Project data (if desired) and record information
  - Define Projection Using ArcToolbox
  - WRITE METADATA!!!
    - Include data collection methods, positional accuracy



What About Recreational Receiver Data?

GPS/GIS Data Integration

- **Recreational grade receivers generally do not allow for feature or attribute collection but do display a position**
- **Positional information from GPS (x, y coordinates) can be entered into separate columns in a database table**
- **Use the Add X,Y Data function to specify x and y values and assign a coordinate system**
- **Most often, this data has not been differentially corrected and thus has lower positional accuracy**



Trimble's GeoXM: Blurring the Line...

GPS/GIS Data Integration

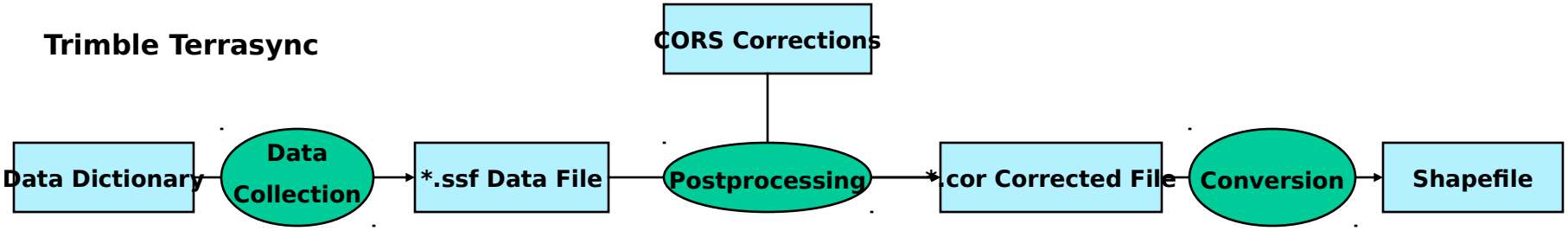
- **Features:**
  - 8 channels
  - 2-5 meter horizontal accuracy after differential correction
  - Integrated WAAS real-time differential corrections
  - 512 MB internal disk storage
  - Backlit color touchscreen

- **Software:**
  - ESRI ArcPad 6.x
  - Trimble GPSCorrect
  - Windows CE

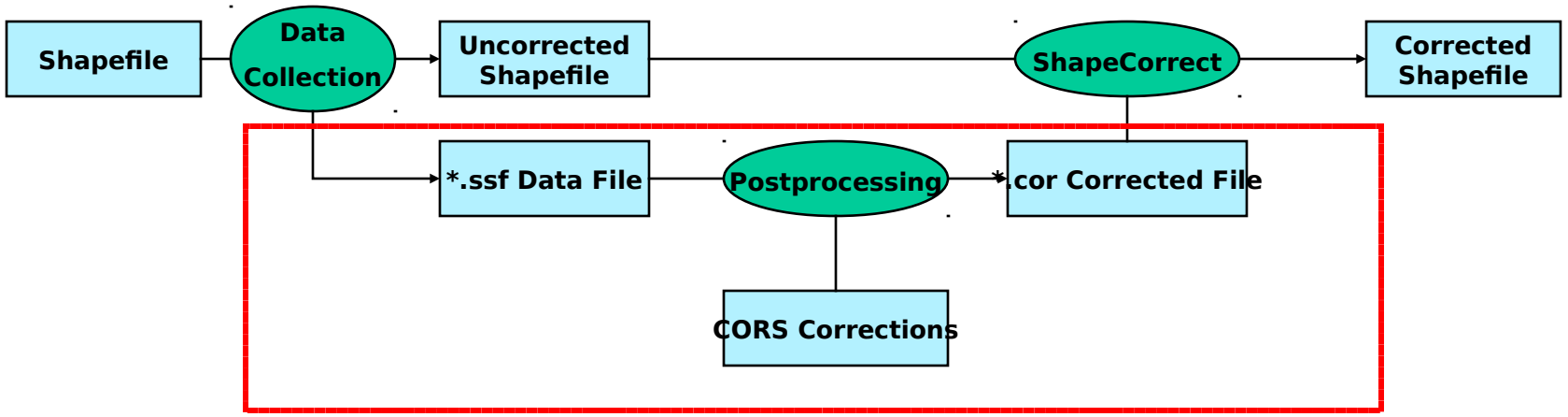
GeoXM Data Collection Process

GPS/GIS Data Integration

Trimble Terrasync



ESRI ArcPad 6.x



Postprocessed Differential Correction

ESRI's ArcPad 6.x

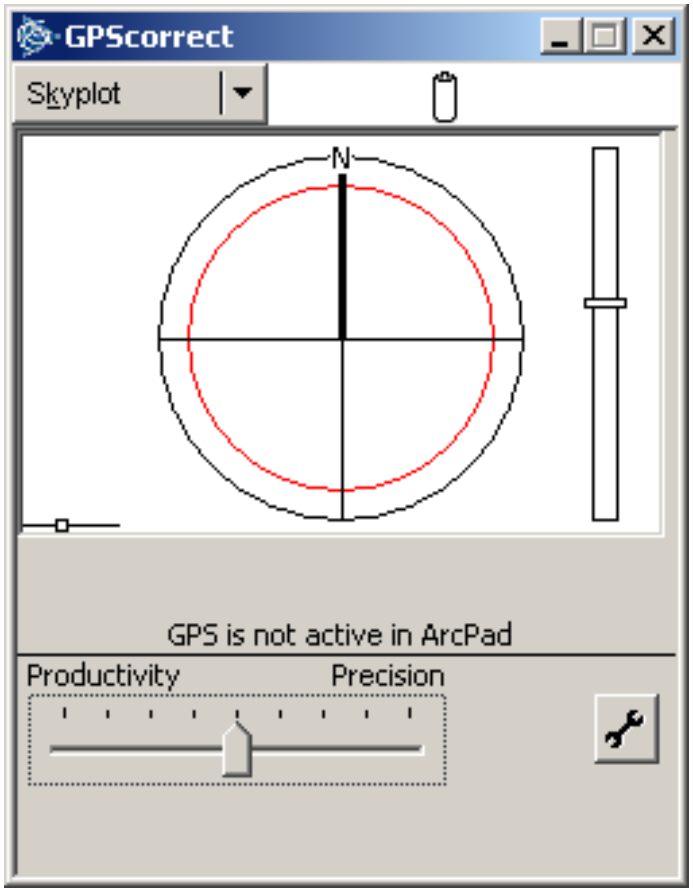
GPS/GIS Data Integration

- **A mobile GIS solution that allows you to collect, edit, and view geographic data in the field**
- **Works with ESRI shapefiles and Mr. Sid® (*.sid) image formats**
- **Data can be created using input from the stylus or GPS receiver**
- **Fully compatible with ArcGIS 8.x**

Trimble's GPSCorrect

GPS/GIS Data Integration

- **An extension that allows for communication between ArcPad and a GPS receiver**
- **Also allows you to collect .ssf files for postprocessed differential correction**
- **Includes integrated planning, and real-time correction information**



Summary

- GPS is composed of a system of three components
- Satellites act as artificial reference points; four are needed to obtain accurate position
- There are two types of error in GPS data collection: internal and external
- Differential correction and a sound data collection plan allow for minimization of positional errors
- Data collection practice makes perfect!
- New units are available that blur the lines between GPS and GIS

Any Questions?

Please contact:

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